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Aizawa et al.

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(54) **PCB CONNECTOR FOOTPRINT**

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H01R 12/70	(2011.01)
H05K 1/11	(2006.01)
H05K 1/02	(2006.01)

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CPC ***H01R 13/6587*** (2013.01); ***H01R 12/7011*** (2013.01); ***H01R 12/7082*** (2013.01); ***H05K 1/0245*** (2013.01); ***H05K 1/116*** (2013.01)

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CPC H01R 13/658; H01R 13/6471
USPC 439/607.07, 607.05, 607.06
See application file for complete search history.

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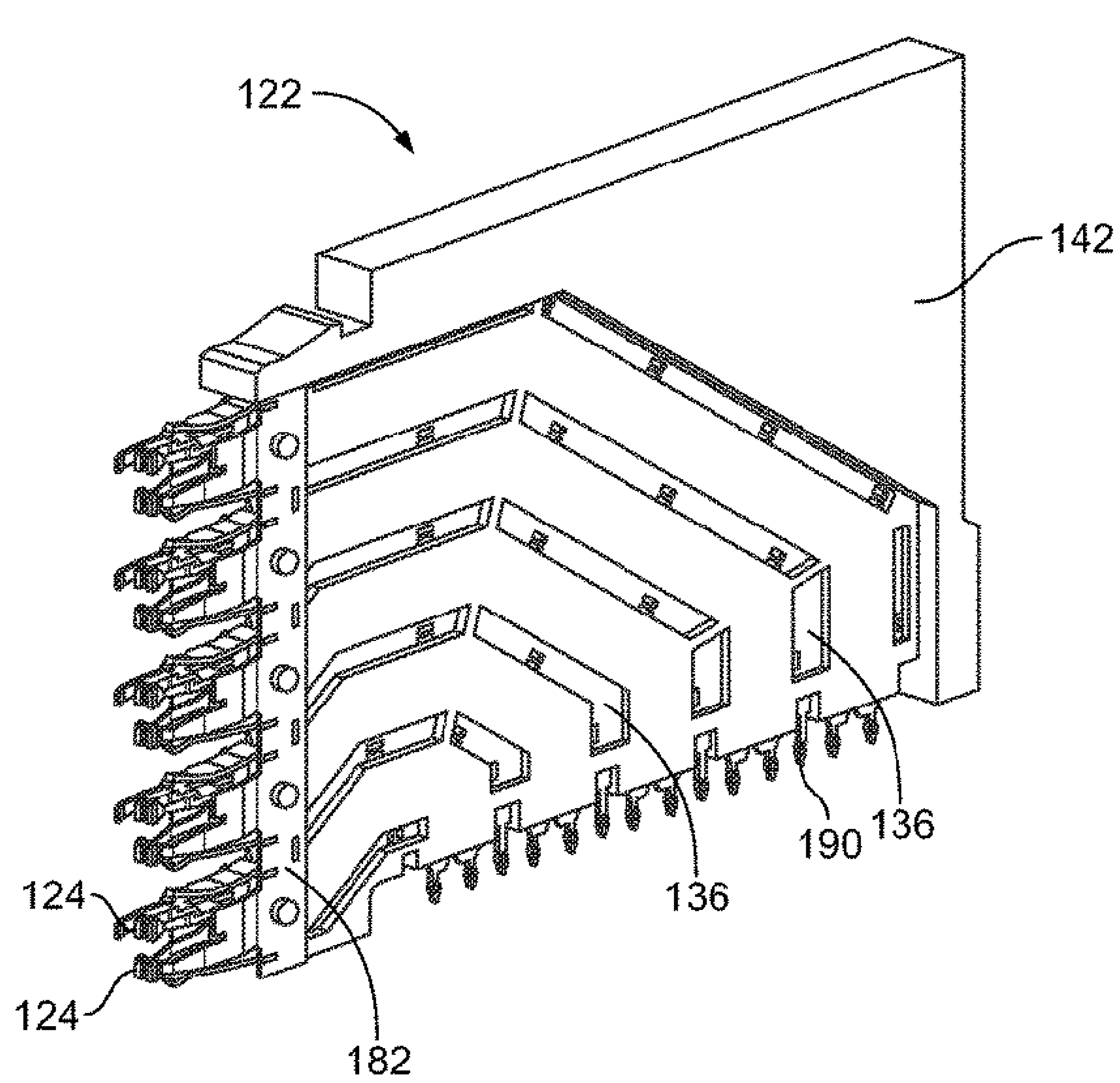
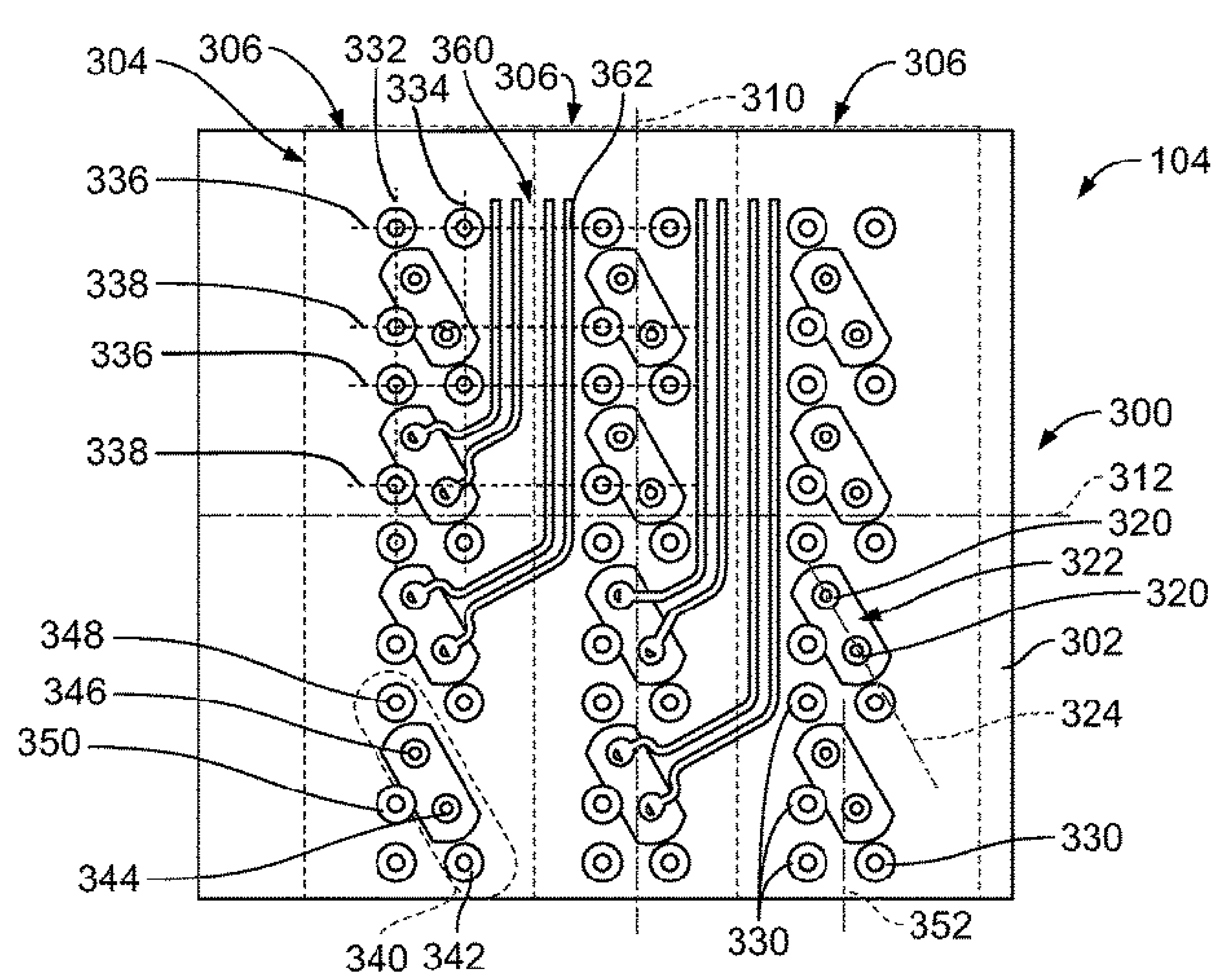
(57) **ABSTRACT**

A PCB includes a substrate having a connector surface with a PCB connector footprint defined along a longitudinal axis and a lateral axis and subdivided into PCB column grouping footprints extending generally parallel to the longitudinal axis. The PCB includes signal vias arranged in pairs along a signal pair axis with a plurality of pairs of signal vias in each PCB column grouping footprint. The signal pair axis is non-parallel to the longitudinal axis, non-parallel to the lateral axis and intersects the longitudinal axis at a lesser angle than the signal pair axis intersects the lateral axis. The PCB includes ground vias at least partially through the substrate. The ground vias are arranged around each of the pairs of signal vias to provide electrical shielding around each of the pairs of signal vias.

20 Claims, 7 Drawing Sheets





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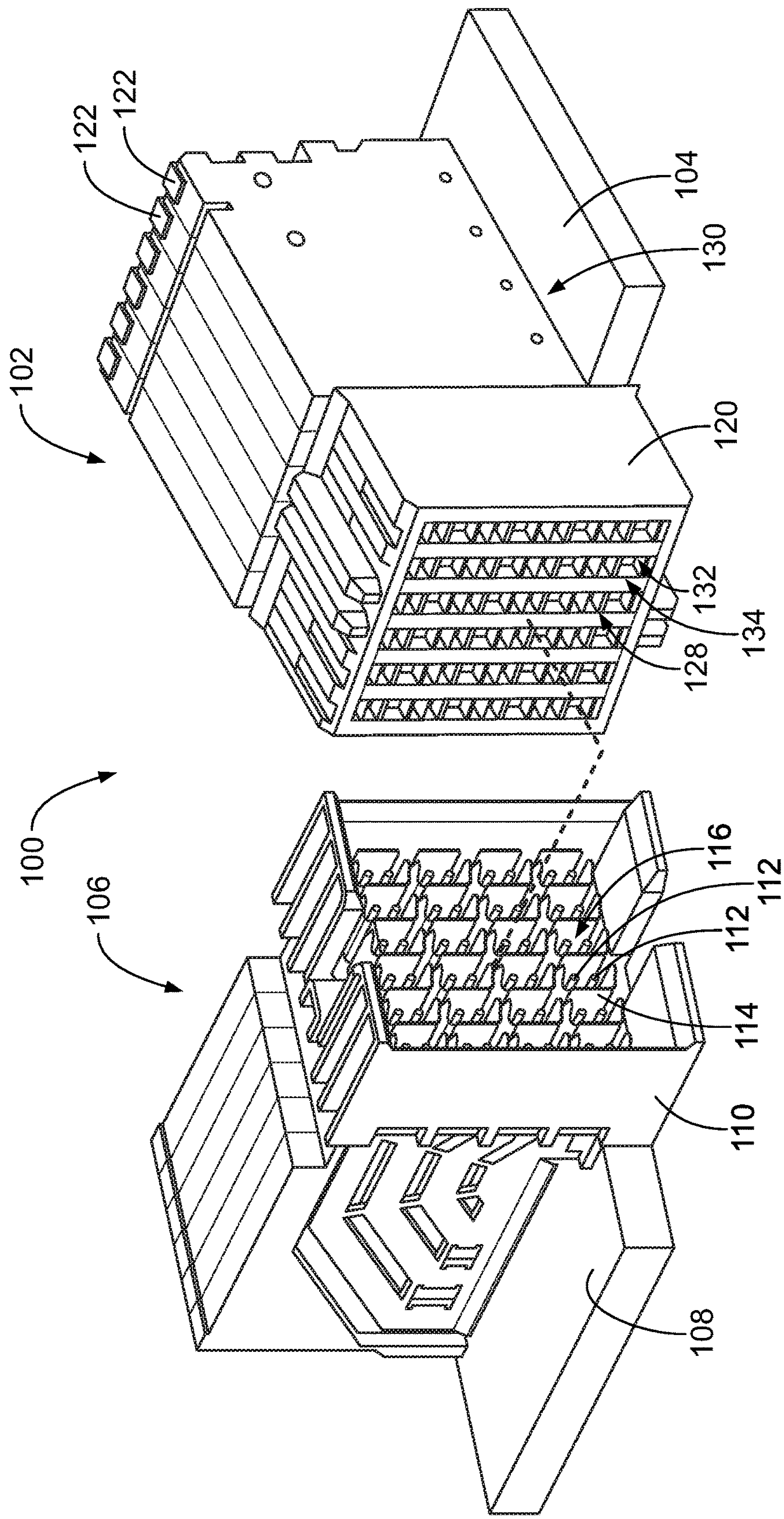
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FIG. 1

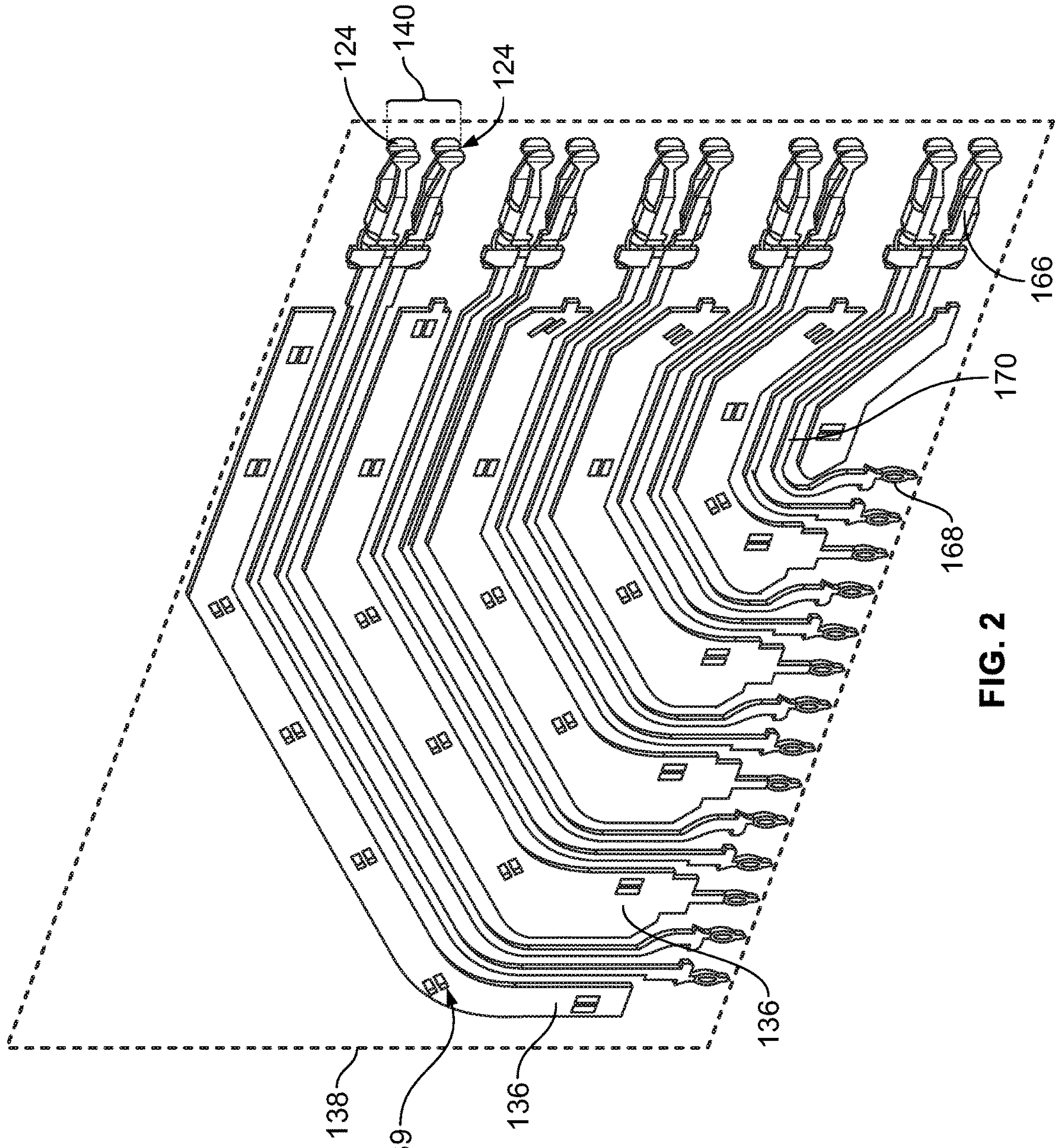

FIG. 2

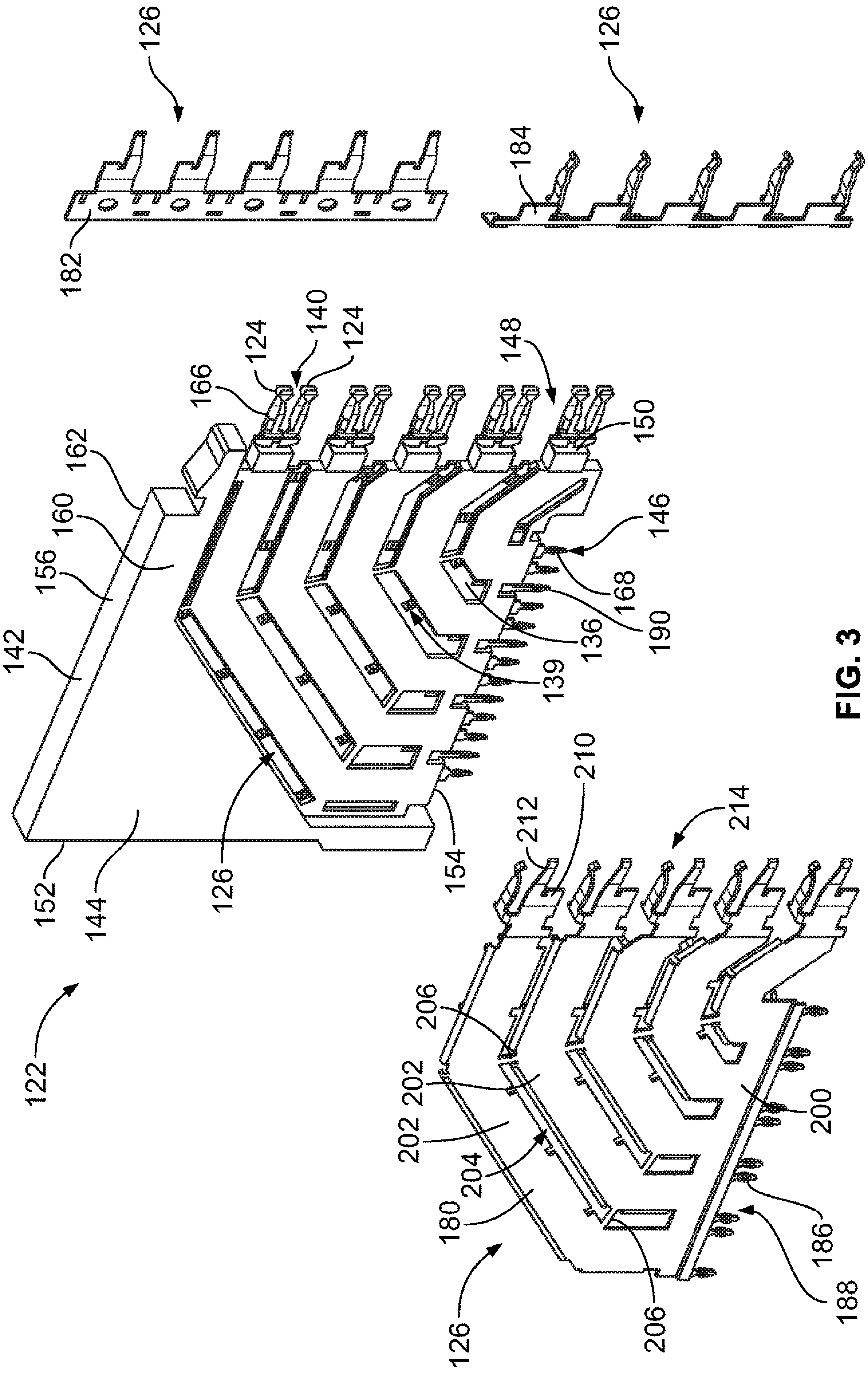
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FIG. 3

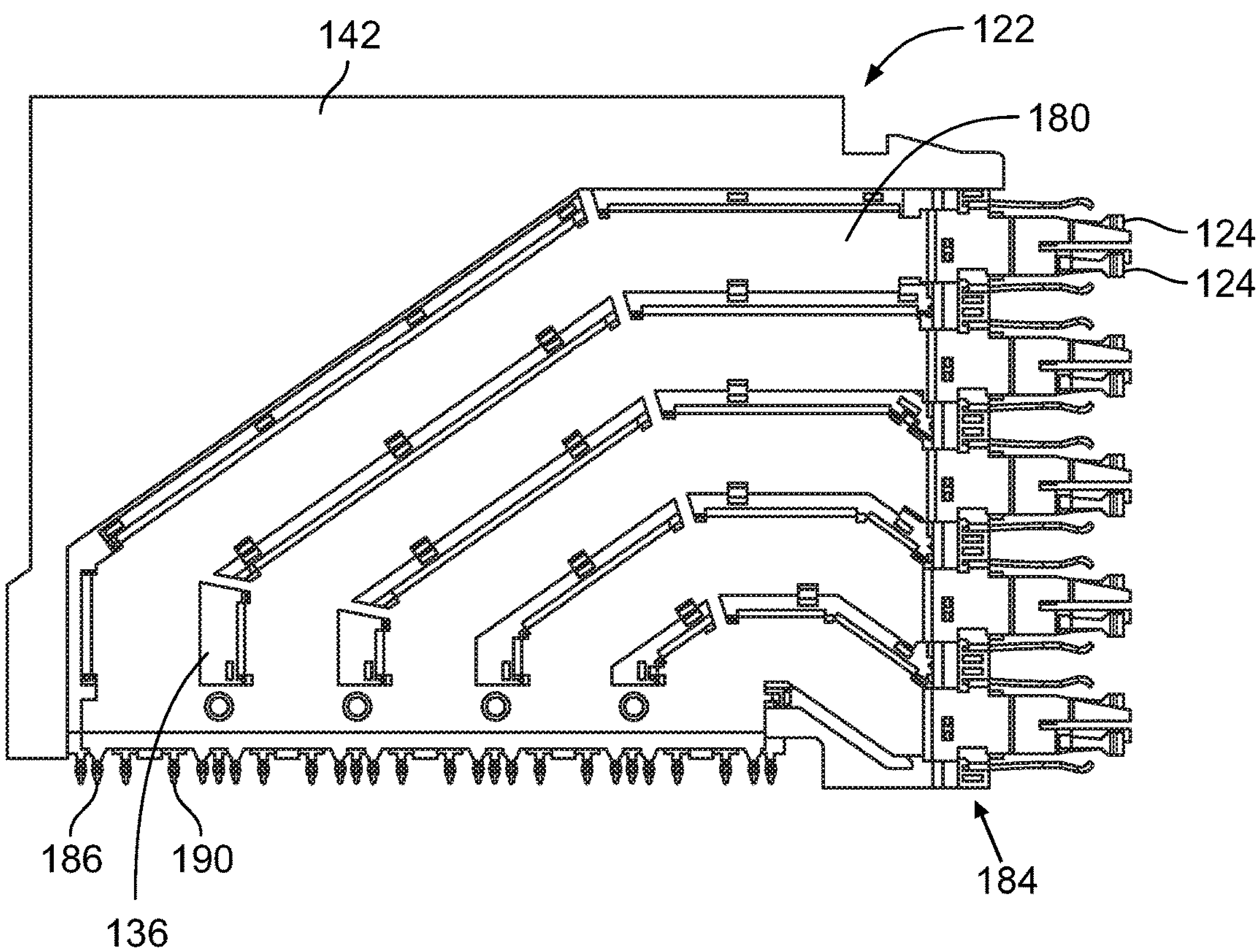

FIG. 4

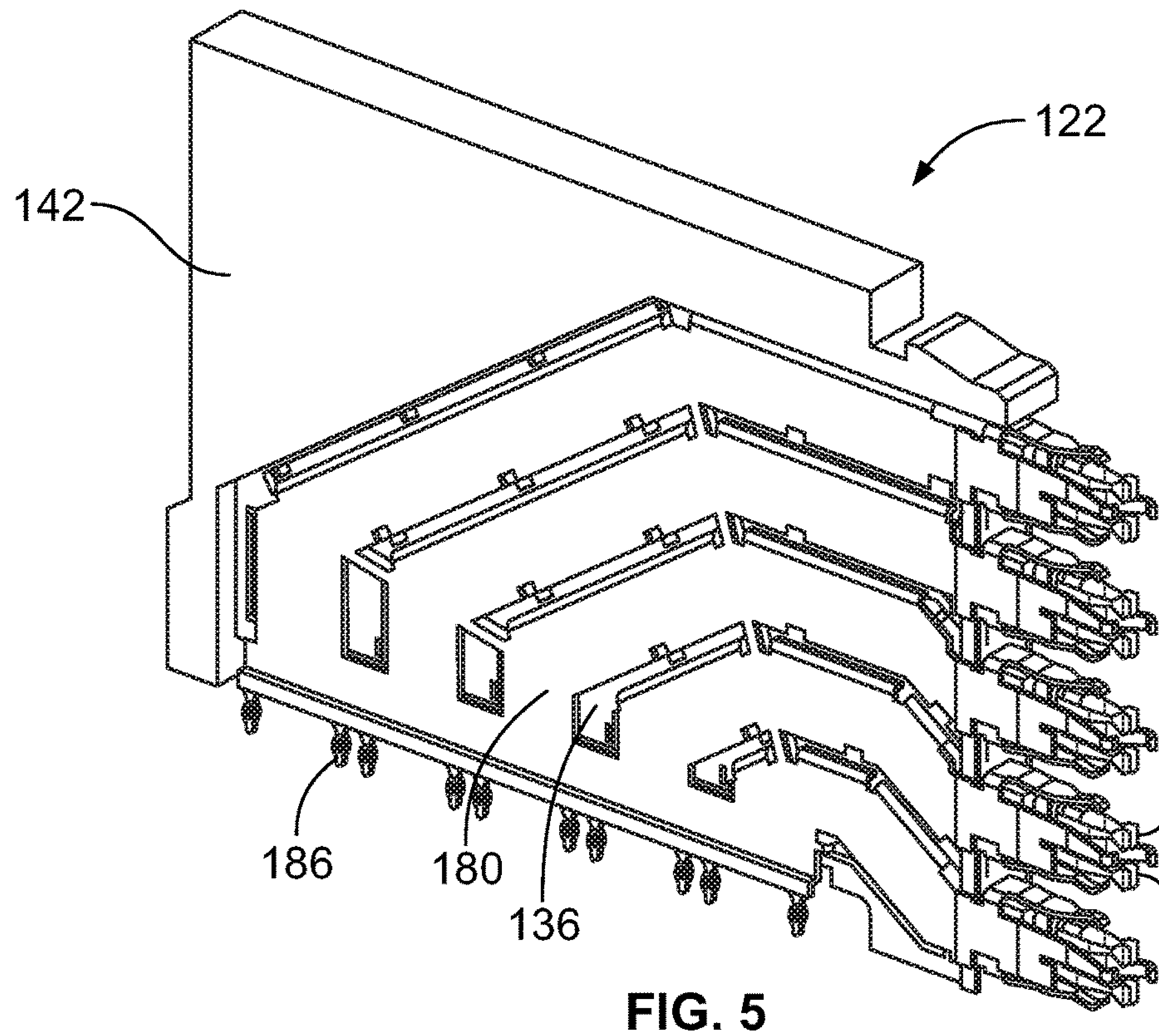

FIG. 5

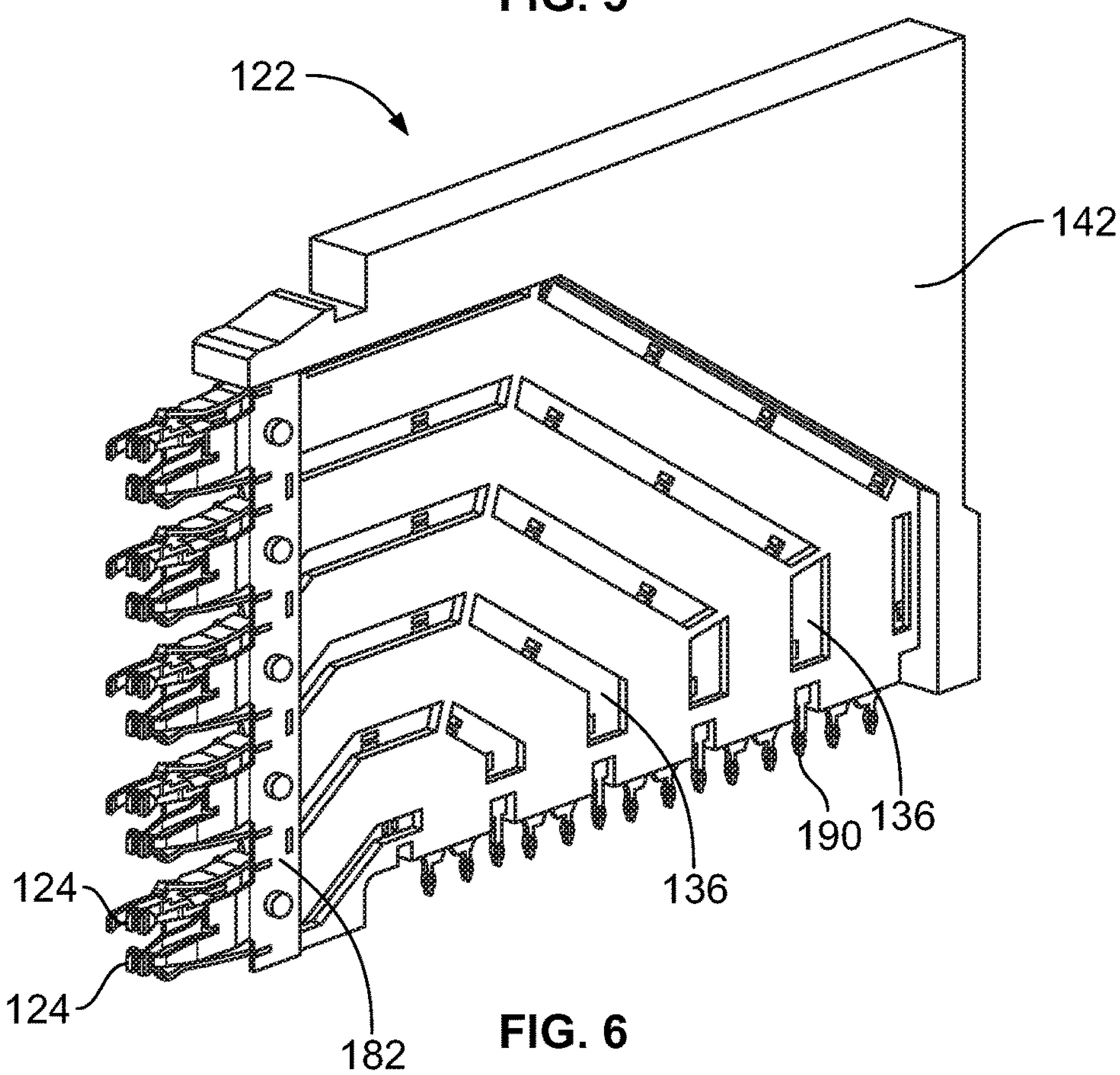

FIG. 6

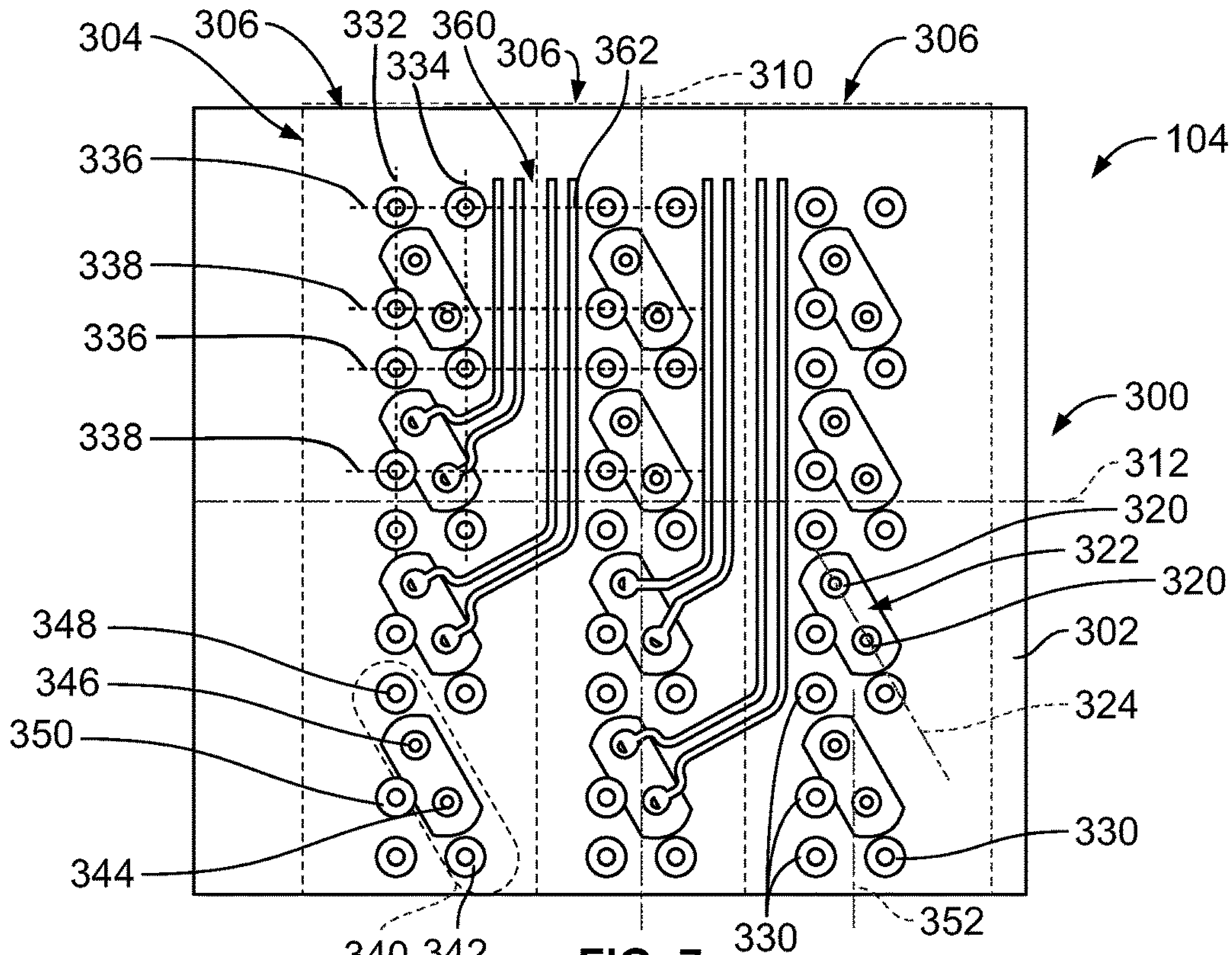

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FIG. 7

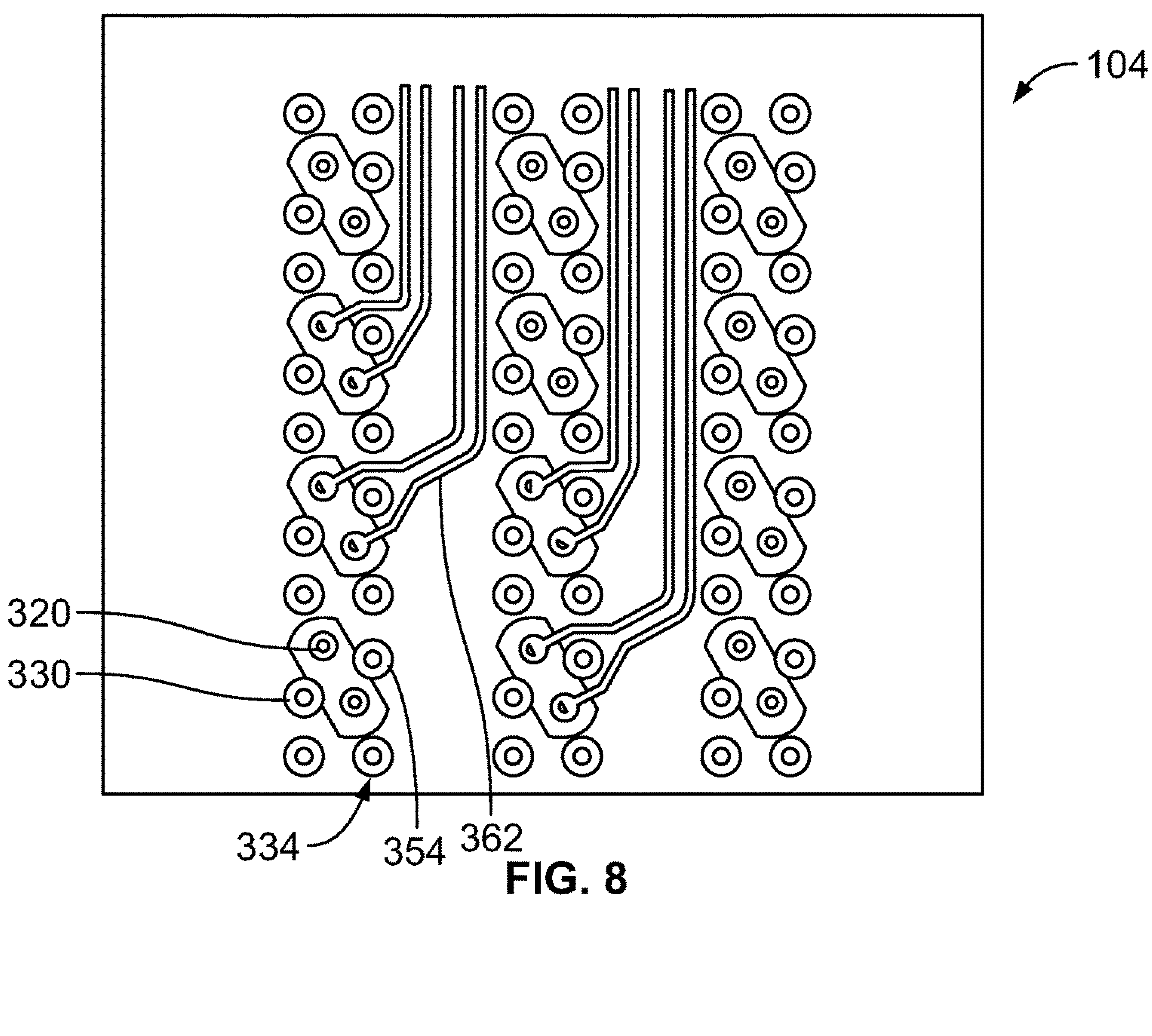

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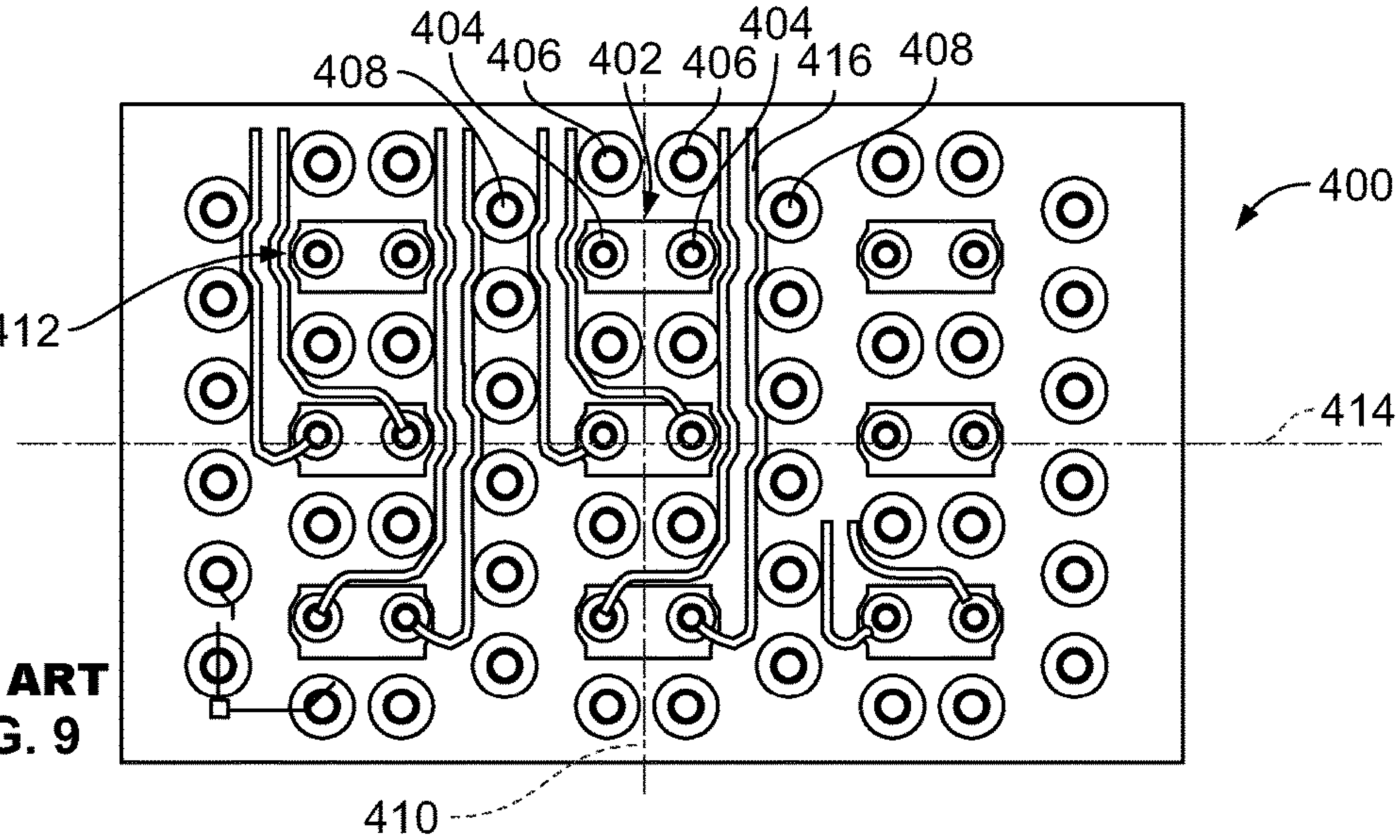
FIG. 8



PRIOR ART
FIG. 9

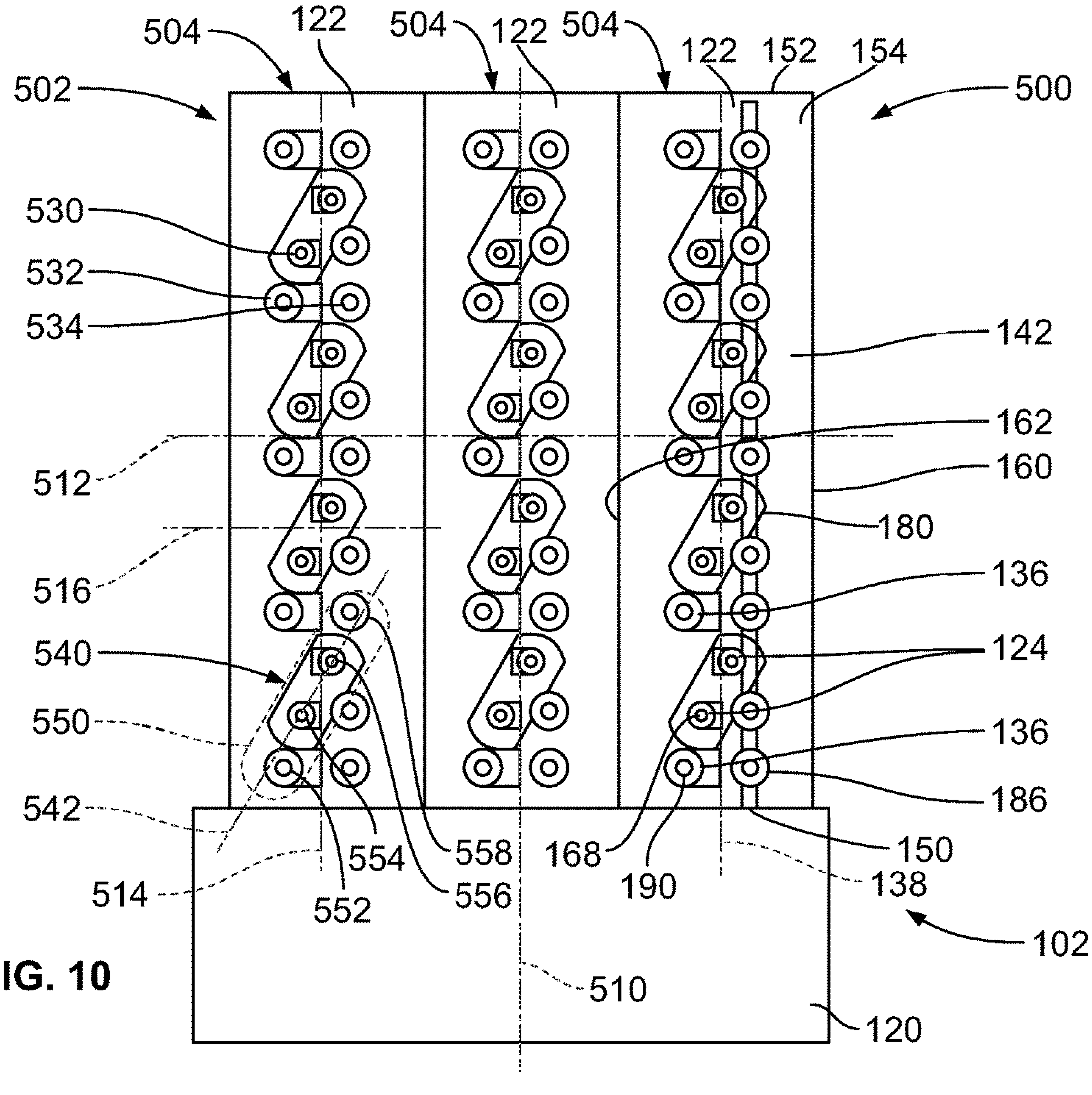


FIG. 10

PCB CONNECTOR FOOTPRINT

BACKGROUND OF THE INVENTION

The subject matter herein relates generally to PCB connector footprints for electrical connectors.

Some electrical systems utilize electrical connectors, such as header assemblies and receptacle assemblies, to interconnect two circuit boards, such as a motherboard and daughtercard. Some known electrical connectors include a front housing holding a plurality of contact modules arranged in a contact module stack. The electrical connectors provide electrical shielding for the signal conductors of the contact modules. For example, ground shields may be provided on one or both sides of each contact module. The signal conductors include mounting portions terminated to the circuit board and the ground shields includes mounting portions terminated to the circuit board. The circuit board includes signal vias and ground vias to receive the mounting portions. For example, the mounting portions are compliant pins and the vias in the circuit board are plated vias.

Circuit board layout and design is complicated, particularly for high density electrical connectors and on circuit boards having multiple components mounted thereto. It is desirable to reduce the number of layers in a circuit board to reduce costs of the circuit board. Routing of the traces is difficult in some circuit boards. Additionally, as the connectors become smaller, the footprints of the connectors are smaller providing less space on the circuit board for providing the vias and routing the traces.

A need remains for a PCB connector footprint and circuit layout for terminating high speed, high density electrical connectors.

BRIEF DESCRIPTION OF THE INVENTION

In one embodiment, a printed circuit board (PCB) is provided for an electrical connector having a plurality of contact modules having signal contacts and ground contacts extending from a mounting end of the electrical connector. The PCB includes a substrate having a plurality of layers. The substrate has a connector surface configured to face the electrical connector and a PCB connector footprint on the connector surface defined below a footprint of the electrical connector. The PCB connector footprint is an area defined along a longitudinal axis and a lateral axis perpendicular to the longitudinal axis. The PCB connector footprint is subdivided into PCB column grouping footprints defined below footprints of corresponding contact modules of the electrical connector. The PCB column grouping footprints are areas extending generally parallel to the longitudinal axis. The PCB includes signal vias at least partially through the substrate. The signal vias are arranged in pairs arranged along a signal pair axis with a plurality of pairs of signal vias in each PCB column grouping footprint. The signal pair axis is non-parallel to the longitudinal axis. The signal pair axis is non-parallel to the lateral axis. The signal pair axis intersects the longitudinal axis at a lesser angle than the signal pair axis intersects the lateral axis. The PCB includes ground vias at least partially through the substrate. The ground vias are arranged around each of the pairs of signal vias to provide electrical shielding around each of the pairs of signal vias.

In another embodiment, an electrical connector system is provided including an electrical connector having a housing having contact modules arranged in a contact module stack received in and extending from the housing. Each contact

module has a dielectric holder, signal contacts held by the dielectric holder, ground contacts held by the dielectric holder and a ground shield held by the dielectric holder. The signal contacts are arranged in pairs carrying differential signals and have signal mounting portions extending from a mounting end of the dielectric holder. The ground contacts have ground mounting portions extending form the mounting end of the dielectric holder. The ground shield has a plurality of ground mounting contacts extending below the mounting end of the dielectric holder. The electrical connector system includes a printed circuit board (PCB) including a substrate having a connector surface facing the electrical connector and a PCB connector footprint on the connector surface defined below a footprint of the electrical connector. The PCB connector footprint is an area defined along a longitudinal axis and a lateral axis perpendicular to the longitudinal axis. The PCB connector footprint is subdivided into PCB column grouping footprints defined below footprints of corresponding contact modules of the electrical connector. The PCB column grouping footprints are areas extending generally parallel to the longitudinal axis. The PCB includes signal vias arranged in pairs arranged along a corresponding signal pair axis. Plural pairs of signal vias are arranged in each PCB column grouping footprint. The signal pair axis is non-parallel to the longitudinal axis, non-parallel to the lateral axis, and intersects the longitudinal axis at a lesser angle than the signal pair axis intersects the lateral axis. The PCB includes ground vias arranged around each of the pairs of signal vias to provide electrical shielding around each of the pairs of signal vias.

In a further embodiment, a contact module is provided including a dielectric holder having first and second sides extending along a longitudinal axis between a front and a rear of the dielectric holder. The dielectric holder has a lateral axis perpendicular to the longitudinal axis between the first and second sides. The dielectric holder has a mating end at the front and a mounting end at a bottom of the dielectric holder. Signal contacts are held by the dielectric holder along a contact plane parallel to the longitudinal axis and defined between the first and second sides. The signal contacts are arranged in pairs carrying differential signals. The signal contacts have mating portions extending from the mating end, mounting portions extending from the mounting end for termination to a printed circuit board (PCB), and transition portions extending through the dielectric holder between the mating and mounting portions. Ground contacts are held by the dielectric holder along the contact plane between corresponding signal contacts. The ground contacts provide electrical shielding between corresponding pairs of the signal contacts. The ground contacts have ground mounting portions extending from the mounting end for termination to the PCB. A ground shield is coupled to the first side of the dielectric holder and provides electrical shielding for the signal contacts. The ground shield is electrically connected to each of the ground contacts. The ground shield has a mounting edge configured to face the PCB and a plurality ground mounting portions extending from the mounting edge for termination to the PCB. Each pair of mounting portions of the signal vias are arranged along a corresponding signal pair axis. The signal pair axis is non-parallel to the longitudinal axis. The signal pair axis is non-parallel to the lateral axis. The signal pair axis intersects the longitudinal axis at a lesser angle than the signal pair axis intersects the lateral axis. The ground mounting portions of the ground contacts and of the ground shield are arranged around the corresponding signal mounting portions of each pair of signal contacts to provide electrical shielding around the signal mounting portions of each pair of signal contacts.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a front perspective view of an electrical connector system including an electrical connector having contact modules formed in accordance with an exemplary embodiment.

FIG. **2** is a perspective view of a portion of one of the contact modules showing signal contacts thereof in accordance with an exemplary embodiment.

FIG. **3** is an exploded view of one of the contact modules in accordance with an exemplary embodiment.

FIG. **4** is a side view of the contact module in an assembled state showing the ground shield.

FIG. **5** is a side perspective view of the contact module in an assembled state showing a ground shield in accordance with an exemplary embodiment.

FIG. **6** is a side perspective view of the contact module showing the ground shield.

FIG. **7** illustrates a PCB in accordance with an exemplary embodiment.

FIG. **8** illustrates the PCB in accordance with an exemplary embodiment.

FIG. **9** illustrates a prior art printed circuit board in accordance with an exemplary embodiment.

FIG. **10** is a bottom view of an electrical connector in accordance with an exemplary embodiment illustrating a footprint of the electrical connector.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a front perspective view of an electrical connector system **100** formed in accordance with an exemplary embodiment. The connector system **100** includes an electrical connector **102** configured to be mounted to a printed circuit board (PCB) **104** and a mating electrical connector **106**, which may be mounted to a printed circuit board (PCB) **108**. The mating electrical connector **106** may be a header connector. Various types of connector assemblies may be used in various embodiments, such as a right angle connector, a vertical connector or another type of connector.

The mating electrical connector **106** includes a housing **110** holding a plurality of mating signal contacts **112** and mating ground shields **114**. The mating signal contacts **112** may be arranged in pairs **116**. Each mating ground shield **114** extends around corresponding mating signal contacts **112**, such as the pairs **116** of mating signal contacts **112**. In the illustrated embodiment, the mating ground shields **114** are C-shaped having three walls extending along three sides of each pair of mating signal contacts **112**. The mating ground shield **114** adjacent to the pair **116** provides electrical shielding along a fourth side of the pair **116**. As such, the pairs **116** of mating signal contacts **112** are circumferentially surrounded on all four sides by the mating ground shields **114**.

The electrical connector **102** includes a housing **120** that holds a plurality of contact modules **122**. The contact modules **122** are held in a stacked configuration generally parallel to one another. The contact modules **122** may be loaded into the housing **120** side-by-side in the stacked configuration as a unit or group. Any number of contact modules **122** may be provided in the electrical connector **102**. The contact modules **122** each include a plurality of signal contacts **124** (shown in FIG. **2**) that define signal paths through the electrical connector **102**. The signal contacts **124** are configured to be electrically connected to corresponding mating signal contacts **112** of the mating electrical connector **106**. In other various embodiments, the electrical connector **102** may be provided without the contact modules **122** and may otherwise hold the signal contacts **124** for mating and mounting to the mating connector and the circuit board.

The electrical connector **102** includes a mating end **128**, such as at a front of the electrical connector **102**, and a mounting end **130**, such as at a bottom of the electrical connector **102**. In the illustrated embodiment, the mounting end **130** is oriented substantially perpendicular to the mating end **128**. The mating and mounting ends **128**, **130** may be at different locations other than the front and bottom in alternative embodiments. The signal contacts **124** extend through the electrical connector **102** from the mating end **128** to the mounting end **130** for mounting to the PCB **104**.

The signal contacts **124** are received in the housing **120** and held therein at the mating end **128** for electrical termination to the mating electrical connector **106**. The signal contacts **124** are arranged in a matrix of rows and columns. In the illustrated embodiment, at the mating end **128**, the rows are oriented horizontally and the columns are oriented vertically. Other orientations are possible in alternative embodiments. Any number of signal contacts **124** may be provided in the rows and columns. Optionally, the signal contacts **124** may be arranged in pairs carrying differential signals; however other signal arrangements are possible in alternative embodiments, such as single-ended applications. Optionally, the pairs of signal contacts **124** may be arranged in columns (pair-in-column signal contacts). Alternatively, the pairs of signal contacts **124** may be arranged in rows (pair-in-row signal contacts). The signal contacts **124** within each pair may be contained within the same contact module **122**.

In an exemplary embodiment, each contact module **122** has a shield structure **126** (shown in FIG. **3**) for providing electrical shielding for the signal contacts **124**. The shield structure **126** is configured to be electrically connected to the mating ground shields **114** of the mating electrical connector **106**. The shield structure **126** may provide shielding from electromagnetic interference (EMI) and/or radio frequency interference (RFI), and may provide shielding from other types of interference as well to better control electrical characteristics, such as impedance, cross-talk, and the like, of the signal contacts **124**. The contact modules **122** provide shielding for each pair of signal contacts **124** along substantially the entire length of the signal contacts **124** between the mating end **128** and the mounting end **130**. In an exemplary embodiment, the shield structure **126** is configured to be electrically connected to the mating electrical connector and/or the PCB **104**. The shield structure **126** may be electrically connected to the PCB **104** by features, such as grounding pins and/or surface tabs.

The housing **120** includes a plurality of signal contact openings **132** and a plurality of ground contact openings **134** at the mating end **128**. The signal contacts **124** are received in corresponding signal contact openings **132**. Optionally, a single signal contact **124** is received in each signal contact opening **132**. The signal contact openings **132** may also receive corresponding mating signal contacts **112** of the mating electrical connector **106**. In the illustrated embodiment, the ground contact openings **134** are C-shaped extending along three sides of the corresponding pair of signal contact openings **132**. The ground contact openings **134** receive mating ground shields **114** of the mating electrical connector **106**. The ground contact openings **134** also receive portions of the shield structure **126** (for example, beams and/or fingers) of the contact modules **122** that mate with the mating ground shields **114** to electrically common the shield structure **126** with the mating electrical connector **106**.

The housing **120** is manufactured from a dielectric material, such as a plastic material, and provides isolation between the signal contact openings **132** and the ground contact openings **134**. The housing **120** isolates the signal contacts **124** from the shield structure **126**. The housing **120** isolates each set (for example, differential pair) of signal contacts **124** from other sets of signal contacts **124**.

FIG. **2** is a perspective view of a portion of one of the contact modules **122** showing the signal contacts **124**. The signal contacts **124** are arranged in an array. The contact module **122** groups the signal contacts **124** together in a stack or column; however portions of the signal contacts may be shifted or jogged and do not necessarily need to be coplanar. FIG. **2** shows guard traces or ground contacts **136** in a contact plane **138** with the array of signal contacts **124**. The ground contacts **136** are arranged between corresponding signal contacts **124**, such as between pairs **140** of the signal contacts **124**. The ground contacts **136** form part of the shield structure **126**. The ground contacts **136** provide electrical shielding between the signal contacts **124**, such as between the pairs **140** of the signal contacts **124**.

In an exemplary embodiment, the signal contacts **124** and the ground contacts **136** are stamped and formed from a common sheet of metal, such as a leadframe. The ground contacts **136** are coplanar with the signal contacts **124**. Edges of the ground contacts face edges of the signal contacts **124** with gaps therebetween. The gaps may be filled with dielectric material to electrically isolate the ground contacts **136** from the signal contacts **124** when the contact module **122** is manufactured, such as by an overmolded dielectric body. In an exemplary embodiment, the ground contacts **136** include slots **139** therein, which may be used to electrically common the ground contacts **136** with other portions of the shield structure **126**.

FIG. **3** is an exploded view of one of the contact modules **122** in accordance with an exemplary embodiment. The contact module **122** includes a frame assembly having the signal contacts **124** and ground contacts **136** with a dielectric frame or holder **142** holding the signal contacts **124** and the ground contacts **136**. The dielectric holder **142** generally surrounds the signal contacts **124** and the ground contacts **136** along substantially the entire lengths thereof between a mounting end **146** at the bottom and a mating end **148** at the front. The shield structure **126** is held by and/or configured to be coupled to the dielectric holder **142** to provide electrical shielding for the signal contacts **124**. The shield structure **126** provides circumferential shielding for each pair **140** of signal contacts **124** along at least a majority of a length of the signal contacts **124**, such as substantially an entire length of the signal contacts **124**.

The dielectric holder **142** is formed from a dielectric body **144** at least partially surrounding the signal contacts **124** and the ground contacts **136**. The dielectric body **144** may be overmolded over the signal contacts **124** and the ground contacts **136**. Portions of the signal contacts **124** and the ground contacts **136** are encased in the dielectric body **144**. The dielectric holder **142** has a front **150** configured to be loaded into the housing **120** (shown in FIG. **1**), a rear **152** opposite the front **150**, a bottom **154** which optionally may be adjacent to the PCB **104** (shown in FIG. **1**), and a top **156** generally opposite the bottom **154**. The dielectric holder **142** also includes first and second sides **160**, **162**, such as a right side **160** and a left side **162**.

In an exemplary embodiment, portions of the shield structure **126** (such as the ground contacts **136**) are at least partially encased in the dielectric body **144**, while other portions of the shield structure **126** are coupled to the exterior of the dielectric body **144**, such as the right side **160** and/or the left side **162** of the dielectric holder **142**. In the illustrated embodiment, the ground contacts **136** are arranged along the contact plane **138** (shown in FIG. **2**) between, and optionally parallel to, the first and second sides **160**, **162**. Additionally, in the illustrated embodiment, portions of the shield structure **126** are coupled to both the right and left sides **160**, **162**, such as at the front **150**.

Each signal contact **124** has a mating portion **166** extending forward from the front **150** of the dielectric holder **142** and a signal mounting portion **168** extending downward from the bottom **154**. Each signal contact **124** has a transition portion **170** (shown in FIG. **2**) between the mating and mounting portions **166**, **168**. The signal contacts **124** are shielded from other signal contacts **124** by the ground contacts **136**. The right side of each signal contact **124** is covered by the shield structure **126** to shield the signal contacts **124** from signal contacts **124** in an adjacent contact module **122**. The mating portions **166** are configured to be electrically terminated to corresponding mating signal contacts **112** (shown in FIG. **1**) when the electrical connector **102** is mated to the mating electrical connector **106** (shown in FIG. **1**). In an exemplary embodiment, the signal mounting portions **168** include compliant pins, such as eye-of-the-needle pins, configured to be terminated to the PCB **104** (shown in FIG. **1**). The signal mounting portions **168** may be jogged to position the compliant pins for termination to the PCB **104**, such as to align with corresponding signal vias in the PCB **104** in accordance with the layout of the vias in the PCB **104**. For example, the compliant pins may be jogged out of the contact plane **138**, such as to one side or the other of the contact plane **138**.

In an exemplary embodiment, the shield structure **126** includes first and second ground shields **180**, **182** and a ground clip **184**. The ground shields **180**, **182** and the ground clip **184** are each separate stamped and formed pieces configured to be mechanically and electrically connected together to form part of the shield structure **126**. The ground shields **180**, **182** and/or the ground clip **184** are configured to be electrically connected to the ground contacts **136** to electrically common all of the components of the shield structure **126**. In various embodiments, the ground clip **184** may be integral with (for example, stamped and formed with) the second ground shield **182** and/or the first ground shield **180**. When assembled, the first ground shield **180** is positioned along the right side **160** of the dielectric holder **142** and the second ground shield **182** is positioned along the left side **162** of the dielectric holder **142**, while the ground clip **184** is provided at the front **150** of the dielectric holder **142**. The ground shields **180**, **182** and the ground clip **184** electrically connect the contact module **122** to the mating electrical connector **106**, such as to the mating ground shields **114** thereof (shown in FIG. **1**), thereby electrically commoning the connection between the electrical connector **102** and the mating electrical connector **106**.

The ground shield **180** electrically connects the contact module **122** to the PCB **104**, such as through compliant pins thereof. For example, the ground shield **180** may include ground mounting portions **186** extending from a mounting edge **188** of the ground shield **180**. The ground mounting portions **186** include the compliant pins configured to be press-fit into corresponding ground vias in the PCB **104**. The ground mounting portions **186** may be jogged to position the compliant pins for termination to the PCB **104**, such as to align with corresponding ground vias in the PCB **104** in accordance with the layout of the vias in the PCB **104**. In other various embodiments, the ground mounting portions **186** may extend straight downward from the mounting edge **188** such that the ground mounting portions **186** are coplanar with the main body of the ground shield **180**.

The ground shield **180** is stamped and formed from a stock piece of metal material. In an exemplary embodiment, the ground shield **180** includes a main body **200** configured to extend along the right side **160** of the dielectric holder **142** (although the ground shield **180** may be reversed and designed to extend along the left side **162** in other various embodiments). The main body **200** may include a plurality of rails **202** separated by gaps **204**, which may be interconnected by connecting strips **206** between the rails **202**. The rails **202** are configured to extend along and follow the paths of the signal contacts **124**, such as between the mating end **148** and the mounting end **146**. For example, the rails **202** may transition from a mating end **214** to the mounting edge **188** of the ground shield **180**.

The ground shield **180** includes mating portions **210** defined by mating beams **212** at the mating end **214** of the main body **200**. The mating portions **210** are configured to be mated with corresponding mating portions of the mating electrical connector **106** (for example, the C-shaped mating ground shields **114**, shown in FIG. **1**). The mating beams **212** may be deflectable mating beams, such as spring beams. Optionally, the mating beams **212** are configured to be received inside the corresponding C-shaped mating ground shields **114** of the mating electrical connector **106**. Alternatively, the mating beams **212** are configured to extend along the outside of the corresponding C-shaped mating ground shields **114** of the mating electrical connector.

The ground contacts **136** are configured to be electrically connected to the PCB **104**, such as through compliant pins thereof. For example, the ground contacts **136** may include ground mounting portions **190** extending from the bottom **154** of the dielectric holder **142**. The ground mounting portions **190** include compliant pins configured to be press fit into corresponding ground vias in the PCB **104**. The ground mounting portions **190** may be jogged to position the compliant pins for termination to the PCB **104**, such as to align with corresponding ground vias in the PCB **104** in accordance with the layout of the vias in the PCB **104**. In other various embodiments, the ground mounting portions **190** may extend straight downward from the bottom **154** such that the ground mounting portions **190** are generally coplanar with the contact plane **138**.

FIG. **4** is a side view of the right side of the contact module **122** showing the first ground shield **180**. FIG. **5** is a side perspective view of the right side of the contact module **122** in an assembled state showing the first ground shield **180**. FIG. **6** is a side perspective view of the left side of the contact module **122** in an assembled state showing the second ground shield **182**. The ground shields **180**, **182** are mechanically connected to the dielectric holder **142**.

The first ground shield **180** is electrically connected to the ground contacts **136** and provides shielding for the signal contacts **124**. The second ground shield **182** is electrically connected to the first ground shield **180** and the ground clip **184**. The ground mounting portions **186** of the first ground shield **180** and the ground mounting portions **190** of the ground contacts **136** extend from the bottom of the contact module **122** for termination to the PCB **104** (shown in FIG. **1**).

FIG. **7** illustrates the PCB **104** in accordance with an exemplary embodiment. The PCB **104** includes a substrate **300** having a plurality of layers. The substrate **300** has a connector surface **302**, which may be the top surface, of the PCB **104**. The connector surface **302** is configured to face the electrical connector **102** (shown in FIG. **1**).

The PCB **104** has a PCB connector footprint **304** (shown generally by dashed lines, only a portion of which is shown in FIG. **7**) on the connector surface **302** defined below the electrical connector **102**. The PCB connector footprint **304** is an area (for example, shadow) generally bounded along the perimeter of the electrical connector **102**. The footprint may include vias, traces and the portions of the circuit board around the vias and the traces. The vias and the traces have a layout in the footprint and the traces may extend beyond the footprint. The PCB connector footprint **304** is defined along a longitudinal axis **310** and a lateral axis **312** perpendicular to the longitudinal axis **310**. The longitudinal axis **310** extends front-to-back, such as from an edge of the PCB **104**. The lateral axis **312** extends side-to-side. The PCB connector footprint **304** has a length along the longitudinal axis **310** and a width along the lateral axis **312**.

The PCB **104** has a plurality of PCB column grouping footprints **306** (shown generally by dashed lines, only portions of which are shown in FIG. **7**). The PCB column grouping footprints **306** may be stacked together to define the PCB connector footprint **304**. For example, the PCB connector footprint **304** is subdivided into PCB column grouping footprints **306** defined below footprints or areas of corresponding contact modules **122** (shown in FIG. **1**) of the electrical connector **102**. While the PCB column grouping footprints **306** are shown and described as being associated with corresponding contact modules, the electrical connector is not limited to having contact modules but rather may otherwise group the signal and ground contacts together into column groupings. The PCB column grouping footprints **306** are areas extending generally parallel to the longitudinal axis **310**. Each PCB column grouping footprint **306** has a length along the longitudinal axis **310** and a width along the lateral axis **312**; however, the lengths and the widths of the footprints **306** may vary.

The PCB **104** has signal vias **320** at least partially through the substrate **300**. The signal vias **320** are arranged in pairs **322** arranged along a signal pair axis **324**. The number of pairs **322** of signal vias **320** depends on the number of pairs of signal contacts **124** in the contact modules **122**. In various embodiments, each PCB column grouping footprint **306** has a plurality of pairs **322** of signal vias **320**. In an exemplary embodiment, the pairs **322** of signal vias **320** are angled and offset. For example, the signal pair axis **324** is non-parallel to the longitudinal axis **310** and non-parallel to the lateral axis **312**. In an exemplary embodiment, the signal pair axis **324** is at a non-45° angle. For example, the signal pair axis **324** intersects the longitudinal axis **310** at a lesser angle than the signal pair axis **324** intersects the lateral axis **312** such that the signal pair axis **324** is closer to parallel to the longitudinal axis **310** than to the lateral axis **312**. In various embodiments, the signal pair axis **324** is at an angle of between approximately 15° and 40° from the longitudinal axis **310**. For example, the signal pair axis **324** may be at an angle of approximately 30° from the longitudinal axis **310**. As such, the signal vias **320** have a long and narrow orientation without being parallel to the longitudinal axis **310**. By arranging the signal vias **320** more narrow (for example, less than 45°), more space is provided between the columns for routing traces without causing the overall PCB connector footprint **304** to widen. The signal pair axis **324** may be at other angles in alternative embodiments, including angles greater than 40° or less than 15°.

The PCB **104** includes ground vias **330** at least partially through the substrate **300**. The ground vias **330** are arranged around each of the pairs **322** of signal vias **320** to provide termination points of the ground mounting portions **186**, **190** (shown in FIG. **3**) and electrical shielding around each of the pairs **322** of signal vias **320**. The ground vias **330** are arranged in columns (for example, parallel to the longitudinal axis **310**) and in rows (for example, parallel to the lateral axis **312**). For example, the ground vias **330** may be arranged in first and second columns **332**, **334** for each PCB column grouping footprint **306** and in first and second rows **336**, **338** for each signal pair **322**. The first rows **336** are provided between adjacent signal pairs **322**, such as forward of and/or rearward of each signal pair **322**, whereas the second rows **338** are provided in positions generally in line with or intersecting the signal pairs **322**. Other positions are possible in alternative embodiments.

In an exemplary embodiment, the ground vias **330** are arranged in via sets **340** with corresponding pairs **322** of the signal vias **320**. For example, each via set **340** includes, in order, a first ground via **342**, a first signal via **344**, a second signal via **346**, and a second ground via **348** arranged generally along the signal pair axis **324**. In an exemplary embodiment, the first ground vias **342** are aligned in the corresponding first row **336** with the second ground vias **348** of the adjacent ground via set **340**, such as the ground via set **340** that is forward of the corresponding ground via set **340**. Outlier ground vias **350** are offset from the corresponding signal pair axis **324**. For example, the outlier ground vias **350** are arranged in the second rows **338** which may be generally aligned with the first signal vias **344** in various embodiments.

In an exemplary embodiment, the first signal via **344** and the second signal via **346** are offset on opposite sides of a longitudinal centerline **352** of the PCB column grouping footprint **306**. For example, because the signal vias **344**, **346** are angled nonparallel to the longitudinal axis **310**, the first signal via **344** is disposed on one side of the centerline **352** while the second signal via **346** is disposed on the opposite side of the centerline **352**.

In an exemplary embodiment, the PCB connector footprint **304** includes trace routing areas **360** between the columns of vias for routing signal traces **362** connected to corresponding signal vias **320**. Optionally, the trace routing areas **360** may be entirely contained within one of the PCB column grouping footprints **306**, or the trace routing areas **360** may extend into both of the adjacent PCB column grouping footprints **306**, or the trace routing areas **360** may be located between adjacent PCB column grouping footprints **306**, such as when there are gaps or spaces between the PCB column grouping footprints **306**. The trace routing areas **360** are provided between the first column **332** associated with one PCB column grouping footprint **306** and the second column **334** associated with the adjacent PCB column grouping footprints **306**. The ground vias **330** are outside of the trace routing areas **360**. The signal vias **320** and the ground vias **330** are tightly arranged such that relatively large gaps are provided between adjacent PCB column grouping footprints **306**, thereby defining the trace routing areas **360**. For example, each trace routing area **360** may have a width approximately equal to the width of a PCB column grouping footprint **306** containing the signal vias **320** and the ground vias **330**.

FIG. **8** illustrates the PCB **104** in accordance with an exemplary embodiment. The PCB **104** illustrated in FIG. **8** is similar to the PCB **104** illustrated in FIG. **7**; however, the PCB **104** illustrated in FIG. **8** includes second outlier ground vias **354** in the second column **334**. The signal traces **362** are routed around the second outlier ground vias **354**.

FIG. **9** illustrates a prior art printed circuit board **400** in accordance with an exemplary embodiment. The print circuit board **400** includes pairs **402** of signal vias **404** and ground vias **406** surrounding the signal vias **404**. The ground vias **406** and the signal vias **404** are arranged in columns **408**. The columns **408** are parallel to a longitudinal axis **410**. The pairs of signal vias **404** are arranged in rows **412** parallel to a lateral axis **414**. Because the signal vias **404** are arranged parallel to the lateral axis **414**, the widths of the footprints are increased as compared to the arrangement of the PCB **104** shown in FIGS. **7** and **8**. Additionally, because the PCB **400** includes columns of ground vias **406** between the columns of signal vias **404**, little space exists for routing of traces **416** from the signal vias **404** without widening the overall footprint on the PCB **400**.

FIG. **10** is a bottom view of the electrical connector **102** in accordance with an exemplary embodiment illustrating a footprint **500** of the electrical connector **102**. The electrical connector **102** includes the contact modules **122** arranged in a contact module stack **502** received in and extending from the housing **120**. The footprint **500** is subdivided by a plurality of contact module footprints **504**. The dielectric holders **142** may define the widths of the contact module footprints **504**. Optionally, gaps may be provided between the contact module footprints **504**. Alternatively, portions of the contact module footprints **504** may overlap in other various embodiments.

The footprint **500** is defined along a longitudinal axis **510** and a lateral axis **512** perpendicular to the longitudinal axis **510**. The longitudinal axis **510** extends front-to-back while the lateral axis **512** extends side-to-side. The footprint **500** has a length along the longitudinal axis **510** and a width along the lateral axis **512**. The contact module footprints **504** extend generally parallel to the longitudinal axis **510**. For example, the dielectric holder **142** has the first and second sides **160**, **162** parallel to a longitudinal axis **514** of the contact module **122** between the front **150** and the rear **152**. The dielectric holder **142** has a lateral axis **516** perpendicular to the longitudinal axis **514**.

The signal contacts **124** have the signal mounting portions **168** extending from the bottom **154** of the dielectric holder **142**. The signal mounting portions **168** may be jogged or bent out of the contact plane **138**, such as being shifted toward the first side **160** or the second side **162**, to arrange tips **530** of the compliant portions at predetermined locations for termination to the PCB **104** (shown in FIG. **7**). For example, the tips **530** may be arranged in a layout, also known as a pinout, which corresponds to the arrangement of the signal vias **320** in the PCB **104**.

The ground contacts **136** have the ground mounting portions **190** extending from the bottom **154** of the dielectric holder **142**. The ground mounting portions **190** may be jogged or bent out of the contact plane **138**, such as being shifted toward the first side **160** or the second side **162**, to arrange tips **532** of the compliant portions at predetermined locations for termination to the PCB **104**. For example, the tips **532** may be arranged in a layout, also known as a pinout, which corresponds to the arrangement of the ground vias **330** in the PCB **104**.

The ground mounting portions **186** of the ground shield **180** extend from the mounting edge **188** of the ground shield **180**. The ground mounting portions **186** may be jogged or bent to arrange tips **534** of the compliant portions at predetermined locations for termination to the PCB **104**. For example, the tips **534** may be arranged in a layout, also known as a pinout, which corresponds to the arrangement of the ground vias **330** in the PCB **104**.

In an exemplary embodiment, the signal mounting portions **168** are arranged in pairs **540**. Each pair **540** of mounting portions **168** of the signal contacts **124** is arranged along a corresponding signal pair axis **542**. The signal pair axis **542** is non-parallel to the longitudinal axis **510** and non-parallel to the lateral axis **512**. In an exemplary embodiment, the signal pair axis **542** is at a non-45° angle. For example, the signal pair axis **542** intersects the longitudinal axis **510** at a lesser angle than the signal pair axis **542** intersects the lateral axis **512**. In various embodiments, the signal pair axis **542** intersects the longitudinal axis **510** at an angle of between approximately 15° and 50°. For example, the signal pair axis **542** may be at an angle of approximately 30° from the longitudinal axis **510**. However, the signal pair axis **542** may be at other angles in alternative embodiments.

The ground contacts **136** and the ground mounting portions **186**, **190** of the ground shield **180** are arranged around the corresponding signal mounting portions **168** of each pair **540** of signal contacts **124** to provide electrical shielding around the signal mounting portions **168** of each pair **540** of signal contacts **124**. In an exemplary embodiment, the ground mounting portions **186**, **190** are arranged in mounting portion sets **550** with corresponding pairs **540** of the signal mounting portions **168**. For example, each mounting portion set **550** includes, in order, a first ground mounting portion **552**, a first signal mounting portion **554**, a second signal mounting portion **556**, and a second ground mounting portion **558** arranged generally along the signal pair axis **542**. In an exemplary embodiment, the first ground mounting portion **552** of one set **550** is aligned in a row with the second ground mounting portion **558** of the adjacent ground mounting portion set **550**.

It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. Dimensions, types of materials, orientations of the various components, and the number and positions of the various components described herein are intended to define parameters of certain embodiments, and are by no means limiting and are merely exemplary embodiments. Many other embodiments and modifications within the spirit and scope of the claims will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. §112(f) unless and until such claim limitations expressly use the phrase "means for" followed by a statement of function void of further structure.

What is claimed is:

1. A printed circuit board (PCB) for an electrical connector having signal contacts and ground contacts extending from a mounting end of the electrical connector, the PCB comprising:

a substrate having a plurality of layers, the substrate having a connector surface configured to face the electrical connector and a PCB connector footprint on the connector surface defined below a footprint of the electrical connector, the PCB connector footprint being an area defined along a longitudinal axis and a lateral axis perpendicular to the longitudinal axis, the PCB connector footprint being subdivided into PCB column grouping footprints generally arranged in columns parallel to the longitudinal axis;

signal vias at least partially through the substrate, the signal vias being arranged in pairs arranged along a signal pair axis with a plurality of pairs of signal vias in each PCB column grouping footprint, the pairs of signal vias being aligned in the corresponding columns parallel to the longitudinal axis, the pairs of signal vias being aligned in corresponding rows parallel to the lateral axis, the signal pair axis being non-parallel to the longitudinal axis, the signal pair axis being non-parallel to the lateral axis, the signal pair axis intersecting the longitudinal axis at a lesser angle than the signal pair axis intersects the lateral axis; and

ground vias at least partially through the substrate, the ground vias being arranged around each of the pairs of signal vias to provide electrical shielding around each of the pairs of signal vias wherein at least one ground via is arranged between adjacent pairs of signal vias within the PCB column grouping footprints and wherein at least one ground via is arranged between adjacent pairs of signal vias in adjacent PCB column grouping footprints.

2. The PCB of claim **1**, wherein the signal pair axis is a non-45° angle relative to the longitudinal axis.

3. The PCB of claim **1**, wherein the signal pair axis is approximately 30° from the longitudinal axis.

4. The PCB of claim **1**, wherein each pair of signal vias includes a first signal via and a second signal via, the first and second signal vias being offset on opposite sides of the longitudinal centerline of the PCB column grouping footprint.

5. The PCB of claim **1**, wherein the PCB connector footprint includes trace routing areas between the signal vias and the ground vias of adjacent PCB column grouping footprints for routing signal traces connected to corresponding signal vias.

6. The PCB of claim **5**, wherein the ground vias are outside of the trace routing areas.

7. The PCB of claim **1**, wherein the ground vias are arranged in rows between the pairs of signal vias.

8. The PCB of claim **1**, wherein the ground vias are arranged in via sets with corresponding pairs of the signal vias, each via set including, in order, a first ground via, a first signal via, a second signal via, and a second ground via arranged generally along the signal pair axis.

9. The PCB of claim **8**, wherein the ground vias include outlier ground vias offset from the corresponding signal pair axis.

10. The PCB of claim **8**, wherein the first ground vias of the ground via sets are aligned in a row parallel to the lateral axis with the second ground vias of the corresponding adjacent ground via set.

11. An electrical connector system comprising:

an electrical connector having a housing having contact modules arranged in a contact module stack received in and extending from the housing, each contact module having a dielectric holder, signal contacts held by the dielectric holder, ground contacts held by the dielectric holder and a ground shield held by the dielectric holder, the signal contacts being arranged in pairs carrying differential signals, the signal contacts having signal mounting portions extending from a mounting end of the dielectric holder, the ground contacts having ground mounting portions extending form the mounting end of the dielectric holder, the ground shield having a plurality of ground mounting contacts extending below the mounting end of the dielectric holder; and

a printed circuit board (PCB) comprising a substrate having a connector surface facing the electrical connector and a PCB connector footprint on the connector surface defined below a footprint of the electrical connector, the PCB connector footprint being an area defined along a longitudinal axis and a lateral axis perpendicular to the longitudinal axis, the PCB connector footprint being subdivided into PCB column grouping footprints defined below footprints of corresponding contact modules of the electrical connector, the PCB column grouping footprints being areas extending generally parallel to the longitudinal axis, the PCB comprising signal vias arranged in pairs arranged along a corresponding signal pair axis, a plurality of pairs of signal vias being arranged in each PCB column grouping footprint, the signal pair axis being non-parallel to the longitudinal axis, the signal pair axis being non-parallel to the lateral axis, the signal pair axis intersecting the longitudinal axis at a lesser angle than the signal pair axis intersects the lateral axis, the PCB comprising ground vias arranged around each of the pairs of signal vias to provide electrical shielding around each of the pairs of signal vias.

12. The electrical connector system of claim **11**, wherein the signal pair axis is a non-45° angle relative to the longitudinal axis.

13. The electrical connector system of claim **11**, wherein the signal pair axis is approximately 30° from the longitudinal axis.

14. The electrical connector system of claim **11**, wherein the PCB connector footprint includes trace routing areas between the PCB column grouping footprints for routing signal traces connected to corresponding signal vias.

15. The electrical connector system of claim **11**, wherein the ground vias are arranged in rows between the pairs of signal vias.

16. The electrical connector system of claim **11**, wherein the ground vias are arranged in via sets with corresponding pairs of the signal vias, each via set including, in order, a first ground via, a first signal via, a second signal via, and a second ground via arranged generally along the signal pair axis.

17. The electrical connector system of claim **16**, wherein the first ground vias of the ground via sets are aligned in a row parallel to the lateral axis with the second ground vias of the corresponding adjacent ground via set.

18. A contact module for an electrical connector comprising:

a dielectric holder having first and second sides extending along a longitudinal axis between a front and a rear of the dielectric holder, the dielectric holder having a lateral axis perpendicular to the longitudinal axis between the first and second sides, the dielectric holder having a mating end at the front and a mounting end at a bottom of the dielectric holder;

signal contacts being held by the dielectric holder along a contact plane parallel to the longitudinal axis and defined between the first and second sides, the signal contacts being arranged in pairs carrying differential signals, the signal contacts having mating portions extending from the mating end, mounting portions extending from the mounting end for termination to a printed circuit board (PCB), and transition portions extending through the dielectric holder between the mating and mounting portions;

ground contacts being held by the dielectric holder along the contact plane between corresponding signal contacts, the ground contacts providing electrical shielding between corresponding pairs of the signal contacts, the ground contacts having ground mounting portions extending from the mounting end for termination to the PCB; and

a ground shield coupled to the first side of the dielectric holder and providing electrical shielding for the signal contacts, the ground shield being electrically connected to each of the ground contacts, the ground shield having a mounting edge configured to face the PCB and a plurality of ground mounting portions extending from the mounting edge for termination to the PCB;

wherein each pair of mounting portions of the signal contacts are arranged along a corresponding signal pair axis, the signal pair axis being non-parallel to the longitudinal axis, the signal pair axis being non-parallel to the lateral axis, the signal pair axis intersecting the longitudinal axis at a lesser angle than the signal pair axis intersects the lateral axis; and

wherein the ground mounting portions of the ground contacts and of the ground shield are arranged around the corresponding signal mounting portions of each pair of signal contacts to provide electrical shielding around the signal mounting portions of each pair of signal contacts.

19. The electrical connector of claim **18**, wherein the signal pair axis is a non-45° angle relative to the longitudinal axis.

20. The electrical connector of claim **19**, the ground mounting portions are arranged in mounting portion sets with corresponding pairs of the signal mounting portions, each mounting portion set including, in order, a first ground mounting portion, a first signal mounting portion, a second signal mounting portion, and a second ground mounting portion arranged generally along the signal pair axis.

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